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Kuwait's Coral Reefs: What Future after the Gulf War?

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Abstract. Surveys of Kuwait's coral island ecosystem before and after the Gulf War reveal that in the marine environment the reefs survived the conflict virutally unscathed. Terrestrially, one island (Qaru) suffered more through lack of care prior to the war than it did from Iraqi occupation. The island that was most heavily defended by the Iraqis (Umm Al Maradem) was attacked by American forces on 24 January 1991. Direct hits on three ammunition dumps and a Rockeye cluster bomb attack has left the island unfit for human occupation for the time being. Ironically, the one island (Kubbar) that lacked any "security" before the war was untouched. The severe dislocation of the Kuwait environmental administration by the war left the onus on politicians, the military and international environmental agencies to provide protection against what appeared to be an ecological catastrophe. The paper addresses this, and considers Value Chain Analysis as a possible non-scientific solution to a non-scientific problem, failing to meet the environment's needs.

Introduction

On 2nd August 1990 Iraq invaded Kuwait. In response the coalition forces, lead by the United States of America began their offensive to liberate Kuwait on January 11th 1991. By the time they had secured sea and air superiority, both the Ministry of Defence and the Ministry of the Environment (UK) were aware of the environmentally sensitive nature of three islands off the coast of Kuwait: Kubbar, Qaru and Umm Al Maradem. These islands are surrounded by the northern-most coral reefs in the western Persian (Arabian) Gulf, and are important breeding areas for sea terns and turtles (Downing 1985).

In the early hours of Thursday 24th January Umm Al Maradem Island was recaptured by US forces. Some days later the Iraqis surrendered Qaru Island[1]. On 25th January the United States reported that oil had been pouring out from Mina Al-Ahmadi oil terminal, and up to five Iraqi tankers, for the past three days. An urgent request was made to the Department of the Environment, alerting the authorities of the risk of oil impacting the islands and seeking permission to assess the environmental situation at first hand with a view to implementing a damage limitation plan. It was refused.

Representations continued in the months following, with three requests being made to the British Government through the House of Commons. Six months after the initial request was made the first ecological survey of the coral islands was carried out.

This paper summarises the findings of the survey, set against over six years of research on the coral reefs of Kuwait (Dowing 1989a). It also addresses a broader, non-scientific issue, by offering a possible solution to the inability of governments and international environmental agencies to act rapidly when faced by an acute environmental disaster.

Materials and Methods

The survey took place from 14th–19th July 1991 and covered all three islands. Given the limited time available, but with the advantage of detailed knowledge of their ecology, the following were completed for each island:

Qualitative surveys of the terrestrial environment
Counts of turtle tracks and nests

[1] In all accounts of the liberation it was incorrectly reported that Qaru Island had been recaptured, and that Umm Al Maradem later surrendered.

Counts of sea terns
Coral transects, fish counts, and counts of the sea urchin *Echinometra mathaei* at sites surveyed prior to the war
Observations on reef health
Measurements of water temperature
Observations on atmospheric pollution

The methods and location maps used for the surveys are as published in Downing 1989c (fish counts), Downing 1989b (coral transects) and Downing and El-Zahr 1987 (sea urchin counts). Counts of sea terns and of turtle nests are compared with the author's unpublished data. The locations for the fish, coral and sea urchin counts and transects were as follows:

Qaru

Fish counts: NW reef edge, bearing to light tower 135°M. Coral transects: W reef from reef edge to shore bearing 050°M, parallel to the jetty; and NW reef from reef edge to shore bearing 135°M to light tower. Sea urchin count: east reef study area (Downing and El-Zahr 1985).

Umm Al Maradem

Fish counts: E reef edge location bearing 285°M to the island light tower. Coral transect: E reef from reef edge to shore bearing 100°M. Sea urchin count: E reef *Porites* beds.

Kubbar

Fish counts: NW reef edge, bearing 135°M to the light tower. Coral transects: S reef from reef edge to shore bearing 020°M to the light tower, and inner NW reef flat bearing 135°M to the light tower. Sea urchin count: outer NW reef flat.

Fish species names are under review. To facilitate comparison with the work listed above the same names are used.

Results

The Terrestrial Environment

Qaru is a small coral cay measuring approximately 270m × 170m. Since before the 1980's it has been inhabited by a contingent of the Kuwait Coast Guard.

Viewed from the air the island appeared to have changed considerably since it was last visited by the author in 1989. On its western side it had been heavily eroded by the sea, and its shape was more circular as a result of sand redistribution. A chain link "security" fence that had been erected to surround the coast guard huts in 1987 lay partly in the sea. A hut had also toppled onto the beach. It is likely that this happened before the invasion because a concrete foundation for a new building had been laid amongst the huts in response to the general disintegration of the habitation. As before, fallen structures had been left to accumulate on the island.

The main impact of the occupying forces was their vandalism of the remaining buildings rather than any impact on the environment itself. No munitions were found on the island, but there were three rifled mortars and several fox holes. There was no sign of oil pollution on the shoreline, nor on the jetty pilings. A layer of soot (fallout from the oil well fires on the mainland) covered the surface of the island above the high tide mark, making a sharp contrast to the beach itself and to the sand-coloured tracks of turtles that had come to nest there.

Five nests were counted. This compares with a maximum of 50 nests in 1984, a count that was made at the end of the season. Emergences occurred while the author was on the island. One green turtle that was closely inspected appeared perfectly healthy and showed no sign of oil contamination. Beach access from the WNW is now denied to the turtles on account of accumulated debris.

Table 1. Counts of four species of sea terns nesting on Kubbar Island: 1984 to 1991.

Date	Bridled	White Cheeked	Lesser Crested	Swift
25 Jul 1984	884		327[1]	
3 Aug 1985	869	223	267	11
22 Jul 1986	916	220	166	2
9 Aug 1987	1618[2]	212	179	1
23 Aug 1988[2]	704	702	641	17
18 Jul 1991	1111	560	167	21

[1]Combined count of white cheeked and lesser crested.
[2]Counts include juveniles.

Table 2. Water temperature data for Qaru, Umm Al Maradem and Kubbar.

Date	Location	Depth (m)	Temp. (°C)
QARU			
1991 July 14	East Reef Flats		27.5
1991 July 14	Jetty	7m	27.0
1991 July 15	North West Edge	10m	28.0
1983 June 19	Mean 3 Stations		26.7
1984 July 9	Mean 8 Stations		29.4
1984 July 22	South East Edge	surface	29.6
1984 July 22	South East Edge	9m	29.0
1984 July 22	North West Bedge	7.5m	29.0
1985 July 20	South East Edge	8m	29.2
1986 July 22	East Reef Flats		31.6
1987 May 29	East Reef Flats		29.2
1988 June 7	South Reef Flats	3m	28.8
1988 June 7	South Reef Flats	surface	29.2
UMM AL MARADEM			
1991 July 16	West Reef Edge	9m	27.4
1991 July 17	East Reef Edge	7m	27.4
1983 June 22	Umm NW (3 readings)		27.2
1984 July 7	Mean 16 Stations		28.9
1984 July 23	East Reef Edge	7m	30.6
1985 July 20	East Reef Edge	7m	29.0
KUBBAR			
1991 July 17	South Reef Edge	7m	28.0
1991 July 18	North West Flats		28.8
1991 July 18	North West Channel	6.5m	28.8
1984 July 16	Mean 8 Stations		30.0
1984 July 18	South West Edge	surface	29.6
1985 July 16	East Reef Edge		27.3
1985 July 16	North West Channel	5m	28.4

Umm Al Maradem was more heavily defended than Qaru. There were 6 ammunition dumps serving three anti-aircraft guns and two rifled mortars. In their attack to liberate the island, US forces dropped a 100kg (approximate) bomb close to the island's main building, and scored direct hits on three of the ammunition dumps. A hut was also destroyed. A Rock-eye cluster bomb was dropped, scattering its 247 bomblets over the southern sector. As a result of the attack unexploded/unstable munitions covered wide areas of the island.

Soot fallout from the mainland oil well fires was very evident. Several turtle tracks were seen, although there were no nests. Nesting on Umm Al Maradem is rare. A population of rabbits used to inhabit the island, but none were seen.

The situation on Kubbar, the northern-most island was quite different. It has never had a permanent Coast Guard presence, and the only structures on the island are a light tower and radio transmitter/navigation facility. There was no sign that the island had been occupied. Oil well soot fallout appeared to be less than on Qaru and Umm Al Maradem.

Kubbar is more heavily vegetated than the other islands and hosts four species of sea tern that breed there each summer. Counts of these birds have been carried out since 1984 (Table 1). Given that the 1987 and 1988 counts included juveniles, the overall number of adults counted in 1991 is considered to be the highest recorded to date.

Turtle nesting on Kubbar is rare, but three sets of turtle tracks were seen on the island. There were no nests.

2. The Marine Environment

Water temperatures at Qaru and Umm Al Maradem were lower when compared to previous years (Table 2). Ambient light levels were also markedly reduced when the smoke plume was overhead.

The dominant corals on all three islands are *Porites spp.*, which occupies large areas of the reef flat, and *Acropora spp.*[2]

In the spring of 1985 there was a widespread coral kill, affecting primarily the shallow water *Porites* beds. However, comparisons of the cover of these two coral groups in the periods before and after the war show, in general, an improvement of the percent living cover (Table 3). Observations in all other areas of the reefs, including along the transect lines, indicated that they were perfectly healthy. There was no sign of oil impact, nor of any ecological problem.

One area of damage was found on the inner reef of Qaru, just south of the jetty. It was caused by a small explosion.

The fish populations also appeared quite normal. Transect data (Tables 4–6) compared to pre-war counts (Downing 1987d) show some changes in the fish population, but these could be attributed to normal variation. Visibility on the Umm Al Maradem transect was sub-optimal, due to very low ambient light levels from the smoke haze.

In the northwestern Gulf, high densities of *Echinometra mathaei* are a feature of reef flat areas that have been subjected to coral kills (Downing 1989b). The densities were high before the Gulf war, and have since remained high (Table 7). At the Qaru east reef flat study site the population structure of the urchins has remained stable since 1985 (Table 8).

Discussion

It has been estimated that 6 to 8 million barrels of oil were deliberately discharged into the northern Gulf during the war, of which almost 2 million barrels were recovered from Saudi waters. As a comprison, the amount discharged annually in the Gulf through operational and other accidental spillages is approximately 2 million barrels (Peter Litheraty, pers. comm.).

In spite of the apparent size of these oil spills and their proximity to the coral islands there was no evidence of impact. It appears that, with the exception of some localised explosives damage underwater, the reefs escaped all damage, at least in the short term. There remains the possibility that

[2] There are two species of *Acropora* on the reefs of Kuwait. A new species, *Acropora* sp. (to be named by Downing and Wallace), is readily distinguished as a table form. The other is *Acropora valida* Dana (1846), a bushy form that has erroneously been confused as being arborescent.

Table 3. A comparison of coral cover before and after the Gulf War from selected sites (see Materials and Methods) at Qaru, Umm Al Maradem and Kubbar. The percentage cover by *Porites* at Umm Al Maradem and Kubbar is given together with that proportion which is living and dead.

Year	% Cover					
QARU. *Porites* and *Acropora.*						
	Porites (living)	*Porites* (dead)	*Acropora* (living)	*Acropora* (dead)	Sand	Rock/Rubble
1987	19	11	7	9	14	40
1991	14	1	24	0	14	47

UMM AL MARADEM. *Porites.*			
	Cover by *Porites*	*Porites* Cover Living	*Porites* Cover Dead
1984	70	67	33
1985	65	15	85
1987	61	41	59
1991	85	51	49

KUBBAR. *Porites.*			
	Cover by *Porites*	*Porites* Cover Living	*Porites* Cover Dead
1987	68	34	66
1991	86	64	36

Table 4. Summary of fish transect results. Numbers of fish recorded at the Qaru transect site.

Size Group (cm)	1–5	6–10	11–15	16–20	21–25	Other
SERRANIDAE						
Cephalopholis hemistiktos		1	4	4	2	
Epinephelus caeruleopunctatus						1@30
Epinephelus suillus						1@30
PSEUDOCHROMIDAE						
Pseudochromis dutoiti	19	53				
CARANGIDAE						
Caragoides bajad			1			
Seriola dumerili					10	
Unidentified CARANJID			6			
LUTJANIDAE						
Lutjanus ehrenbergi				1	1	
HAEMULIDAE						
Plectorhinchus cinctus						1@35
LETHRINIDAE						
Lethrinus nebulosus						1@30
SPARIDAE						
Acanthopagrus bifasciatus				1	1	
Diplodus kotschyi			1			
CHAETODONTIDAE						
Chaetodon melapterus			1			
Chaetodon nigropunctatus		1				
Heniochus acuminatus			1			
POMACENTRIDAE						
Chromis xanthopterygia	243	230				
Neopomacentrus sindensis	34					
Abudefduf saxatalis			23			
LABRIDAE						
Labroides dimidiatus		1				
Halichoeres stigmaticus	54					
Thalassoma lunare		7	12			
SCARIDAE						
Scarus persicus			1		1	
Scarus sp.		1	5			
POMACANTHIDAE						
Pomacanthus maculosus		1	1	2		
ACANTHURIDAE						
Zebrasoma xanthurum			2	1		
SIGANIDAE						
Siganus canaliculatus		2	1			
BLENNIIDAE						
Ecsenius pulcher	32	8				

Other fish seen outside the limits imposed by the transect line were:
Scolopsis ghanam
An unidentified SCARID

long term damage may become evident as a result of soot fallout, from polyaromatic hydrocarbons, for instance (R. Hilliard, pers. comm.).

Water temperatures were, however, approximately 1.5°C lower at Qaru and Umm Al Maradem than in previous years when measurements were taken. This is attributed to the dense cloud of atmospheric pollution from the burning oil wells, the last of which were extinguished in November 1991. The reefs of the northwestern Persian Gulf are distinguished by the extreme range of water temperature that they tolerate (Downing 1984; Coles and Fadlallah 1991). Reef base temperatures at Kubbar have been measured as low as 13.2°C. The risk of a depression of water temperature below that tolerated by the coral community during the winter

Table 5. Summary of fish transect results. Numbers of fish recorded at the Umm Al Maradem transect site.

Size Group (cm)	1–5	6–10	11–15	16–20	21–25	Other
SERRANIDAE						
Cephalopholis hemistiktos				2	1	
Epinephelus suillus						1@50
Epinephelus multinotatus						1@40
PSEUDOCHROMIDAE						
Pseudochromis dutoiti		16				
Pseudochromis persicus		4				
CARANGIDAE						
Caragoides bajad				3		
Selaroides leptolepis		147				
NEMIPTERIDAE						
Scolopsis ghanam			2			
MULLIDAE						
Upeneus doriae			1			
Parupeneus margaritatus				1		
CHAETODONTIDAE						
Chaetodon nigropunctatus		7				
Heniochus acuminatus			2			
POMACENTRIDAE						
Chromis xanthopterygia		281				
Neopomacentrus sindensis	520	293				
LABRIDAE						
Labroides dimidiatus		1				
Halichoeres stigmaticus	5	2				
Thalassoma lunare			3	1		
POMACANTHIDAE						
Pomacanthus maculosus		2		1	1	
BLENNIIDAE						
Ecsenius pulcher	3	23				

Other fish seen outside the limits imposed by the transect line were: *Abudefduf saxatalis, Siganus canaliculatus, Cheimerius nufar.*

of 1991/1992, and the need to resurvey the reefs at the end of Spring 1992 have already been noted (Downing 1991). Minimum air temperature approached 0°C at Kuwait International Airport at the beginning of January 1992.

The main concern is with the terrestrial environment of Qaru and, in particular, Umm Al Maradem. These islands were both occupied by Iraqi forces. Although the buildings were thoroughly vandalised most of the damage on Qaru Island related to the period *prior* to the war. Structures that ceased to be of any use were simply abandoned, and additional dwellings constructed elsewhere. On a small island such a construction policy has a considerable impact. Prior to the war the reef continued to be a dumping ground for refuse, in spite of the environmental authorities being aware of the practice. Beach access from the WNW is now denied to emerging turtles on account of accumulated debris and the fallen security fence that in fact served no useful purpose before the war.

The recapture of Umm Al Maradem in January turned a relatively stable munitions area into a highly unstable one. The release of cluster bombs over sandy desert areas typically results in about 30% of the bomblets not exploding on impact. A number of these undetonated bomblets remain scattered around the southern end of the island. Although three of the six munitions dumps were still intact at the time of the survey, the ordnance in the remaining three was scattered as a result of being hit. It was in a dangerous and unstable state. The danger to animal life is not judged great, but the island will remain unfit for human habitation until the ordnance is cleared. Care will also have to be taken when clearance is carried out to minimise impact on the habitat.

In contrast, Kubbar remained undisturbed by the events of the war, even though it was closest to the Mina Al-Ahmadi (Sea Island) discharge. There was no sign of oil impact. The state of the reef community was healthy. The terrestrial vegetation,

Table 6. Summary of fish transect results. Numbers of fish recorded at the Kubbar transect site.

Size Group (cm)	1–5	6–10	11–15	16–20	21–25	Other
SERRANIDAE						
Cephalopholis hemistiktos				2		
Epinephelus suillus						1@40
PSEUDOCHROMIDAE						
Pseudochromis dutoiti	2	15	1			
Pseudochromis persicus	1	5				
APOGONIDAE						
Cheilodipterus arabicus		1				
LUTJANIDAE						
Lutjanus ehrenbergi			1			
HAEMULIDAE						
Plectorhinchus ?sordidus			1			
NEMIPTERIDAE						
Scolopsis ghanam	7	1	1			
Scolopsis ruppelli		1	7			
SPARIDAE						
Diplodus kotschyi		1				
Acanthopagrus latus			2			
CHAETODONTIDAE						
Chaetodon nigropunctatus		2	1			
POMACENTRIDAE						
Chromis xanthopterygia	2	4	8			
Neopomacentrus sindensis	696	113				
LABRIDAE						
Halichoeres stigmaticus	48	5				
POMACANTHIDAE						
Pomacanthus maculosus			3	2	1	
BLENNIIDAE						
Ecsenius pulcher	7	9				
GOBIIDAE						
Cryptocentrus lutheri	5	10				

albeit dry as a result of the summer, had grown well over the winter of 1990/1991. There was evidence that American forces had landed on the island, but none that it had been otherwise occupied.

Most striking was the number of sea terns nesting on the island. Competition for breeding space, particularly amongst the white cheeked tern, was heightened. Some eggs had been laid unusually close to the high tide mark, apparently for want of space. Inspection of the chicks, both on the nests and in their creches by the water's edge showed no indication of abnormality. Judging by their numbers and state of health, food was not in short supply. At least to that level, therefore, one may deduce that there was no disruption of the food chain.

It can be concluded that the coral and coral island ecosystem off the coast of Kuwait escaped the war lightly. However, it would be wise to continue monitoring the situation over the next two or three years to see whether any longer term perturbations become evident.

* * *

At the time the oil was released into the Gulf there was international outrage at what was labelled "eco-terrorism", but in relation to Kuwait no effective action was forthcoming. The logical steps to take would have been to establish: what part of the environment was actually at risk, how real the risk was, and what could be done to alleviate or prevent impact.

Once the first two steps had been taken (these happened very rapidly), it was imperative to then obtain field evidence of the actual situation. At this stage of the war the coalition forces had control of the sea and air. Umm Al Maradem had fallen to U.S. forces and Qaru had been surrendered. Given

Table 7. *Echinometra mathaei* density data. Qaru east reef study site, Umm Al Maradem east reef flats, and Kubbar north west reef study site.

QARU Date	No./m²	s.e.m.
Nov 1985	29	3.7
Feb 1986	28	2.2
Oct 1986	29	2.3
Apr 1987	29	2.8
Nov 1988	29	3.1
Jul 1991	35	4.3
UMM AL MARADEM		
Date	No./m²	
Sep 1986	32	–
Jul 1991	60	–
KUBBAR		
Date	No./m²	
Nov 1985	47	3.0
Jan 1986	27	3.7
Jul 1986	89	4.4
Feb 1987	52	2.8
Jul 1991	50	6.6

Table 8. Change in population structure of *Echinometra mathaei*. Qaru Island east reef study Site.

Date	Mean Test Diameter (mm)	2 × s.e.m.
Nov 1985	37	2.2
Feb 1986	40	1.4
Oct 1986	40	2.4
Apr 1987	40	2.4
Nov 1988	41	1.4
Jul 1991	40	1.2

the preparation and ground work that had been covered prior to the release of the oil, it would have been possible to establish an expert in the areas within 24 hours of the decision being taken.

In actuality it took 5 months *after* the end of the conflict before the survey, reported in this paper, was carried out.

Meanwhile the Ecological Consequences of the Gulf War had been debated in the House of Commons (15th March 1991). The plight of the islands was once again acknowledged, but with little direct action.

The above account is probably not unfamiliar to those who have attempted to deal with critical environmental needs. In this case, the warnings to the authorities both before and after the oil was released into the Gulf are well documented. There is no doubt that had the will been there, action could have been taken.

The question to address is whether a methodology exists that overcomes the combined problems of bureaucracy, self interest and internal politics that prevent decision makers from allowing action to proceed. These are problems that face all forms of organisation. Fortunately, workable solutions to these problems are available and some organisations have gone a long way to overcome them.

The reason why most scientists and the organisations for which they work are largely ignorant of these methodologies is that they have been shielded from the economic rigours that face the business community. Commercial organisations have long faced the reality that they must work to generate profit. From profit comes the means to grow the company or business and to satisfy, where appropriate, the shareholders whose money is invested in it. Most operate in competition with others within a defined marketplace. If they cannot compete successfully, they will in time be no longer viable, and go out of business.

The results of successful competition are nowhere more apparent than in Japan. The "economic miracle" propagated by its industry has long impressed other nations, but it has only relatively recently become general knowledge that it was methodology from the United States (Walton 1986) that formed one of the bases for Japan's post World War II success. Variants of this methodology have, when applied in the West returned remarkable results in commercial organisations that would otherwise have succumbed to competition. The Xerox Corporation is a case in point.

The methodology comes in various guises, but is commonly known as Total Quality Management (TQM). This name can be somewhat misleading as it implies the quality of a product, where zero defect is the goal. It goes beyond this, however, incorporating a number of techniques, two of which are relevant to matters of environmental importance and to the subject of this paper.

The first technique is Value Chain Analysis, introduced by Porter (1985). Two key concepts emerge from it:

1. Every organisation has an *external customer* to which the organisation must be completely oriented, and whose needs must be met. If they are met and the customer is completely satisfied competitors will be kept at bay and business is likely to grow.
2. Within any organisation each entity has an *internal customer* and an *internal supplier*. The entity might be a department or an individual.

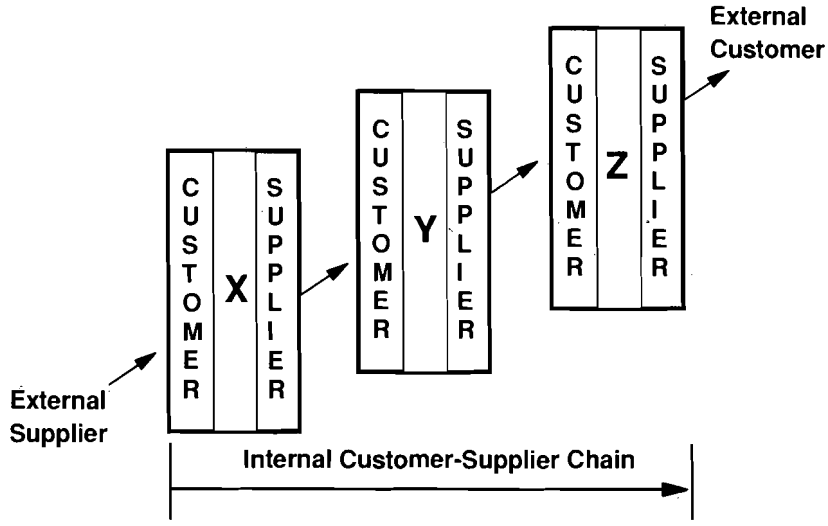

Fig. 1. Three entities linked as customers/suppliers in a value chain.

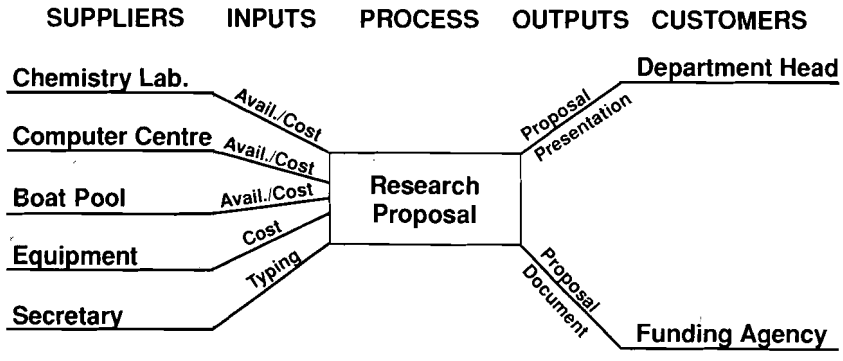

Fig. 2. Process Analysis model, as applied to the completion of a research proposal.

Fig. 3. Value chain, applied to the environment as the ultimate customer.

In the example shown in Fig. 1, entity Y's internal supplier is X, and its internal customer is Z. X, Y and Z are linked in an internal supplier/customer chain. It is only when each link in this chain is properly forged that the organisation, as a whole, can expect to meet the external customer's needs.

The second technique, Process Analysis, is a method by which these links are forged. Essentially it considers one activity at a time. A familiar example would be the completion of a research proposal. It analyses, on the one had, what inputs are required and from whom they should be supplied in order to complete that activity. On the other hand it analyses the required outputs and the customers to which the outputs are due (Fig. 2). Process Analysis not only forces focus on the needs of the suppliers and customers, but also makes it quite obvious where nonproductive activities (known as "waste") are occurring. If all processes are periodically re-examined in a critical manner, and suitable changes introduced wherever improvements can be achieved, top quality performance will follow.

How does this relate to the Kuwait coral island ecosystem in particular and to the environmental context as a whole? The failure to act on time to avert what appeared to be an almost certain ecological disaster in the northern Gulf was in part due to the lack of understanding that the environment was the *external customer* (Fig. 3). Customer focus never existed, and because of that the needs of that customer, the environment, were not met. If the methodologies of TQM, which are extremely simple and obvious to understand, had been followed by the parties concerned, then the very rapid deployment of experts to the islands would have occurred as soon as the oil had been detected, and ground truthing of the data collected by remote sensing would have begun almost immediately. The methodologies used in TQM expose very rapidly where the problems lie, and which parts of the Value Chain are weak. They also provide a "non-blame" environment in which to address those problems and resolve them.

For TQM to work those people forming the Value Chain must understand the fundamental principles involved. Unscientific methodology is readily apparent to scientists because they have been trained in scientific methodology. In the same way it is clear when TQM principles are being flaunted, with the usual result that the customer's needs are not being met. When that customer is an ecosystem under threat, it is perhaps time that scientists and their organisations look to methodologies that work.

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